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Wavelet coefficients and statistical parameters in fault diagnosis

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Abstract

In our work, the induction motor stator current is analyzed with discrete wavelet transform to distinguish the healthy and faulty spectrum. The inter-turn short circuit fault is created in real time and it is analysed. The wavelet transform uses wavelet coefficients and its statistical parameters as fault indicators. The results have to be compared to give better solution in fault diagnosis.

Keyword- Discrete Wavelet Transform (DWT), Fault identification, Induction motor, Statistical parameters and Wavelet coefficients.

Introduction

Condition monitoring plays a very important role in industries as they avoid unknown shut down time, help in planning the future maintenance, increase the performance and as overall improves the profit of the industry. Induction motors are popularly used motors in industries. Any failures in the machine will affect the entire progress of the industry. Therefore condition monitoring of electrical machines are very important role.

The conventional approaches in fault diagnosis are pressure monitoring, vibration measurements, artificial neural networks & fuzzy logic and Motor Current Signature Analysis (MCSA). MCSA based fault diagnosis are mostly preferred fault diagnosis technology as it is very easy to acquire the induction motor stator current and process it. MCSA based fault diagnosing methods are Park's vector approach, Fast Fourier transform (FFT), Short Time Fourier Transform (STFT).

Park's vector approach is used to diagnose different type of faults. Park's approach is applied in star connected system as the zero sequence component of the delta connected systems circulated in the loop itself[1&2]. FFT is a popularly used technique in fault diagnosis. But it is difficult to apply with accuracy since it faces the problems like frequency resolution, magnitude accuracy and data processing [3&4]. Also FFT is not a reliable technique for ort circuit fault detection [3]. STFT provides both the time and frequency information. To obtain good resolution, it requires high processing power [5]. The spectrogram obtained from STFT is useful technique to apply for the signals having time varying frequencies [4]. Discrete wavelet Transform (DWT) [6&7] is an advanced technique which overcomes the disadvantages of all the above discussed and it can be used in induction motor fault diagnosis. Also it gives better solution compared to the conventional techniques like acoustic pressure and vibration analysis [9&10].

Every change in the operating condition of the induction motor appears at the supply side as transient phenomena and sudden variations of the load power and therefore of the current [5]. The fault occurs in the stator can be classified into stator fault, rotor fault, bearing fault and eccentricity fault. From the stator current analysis, the fault appears in the motor can be identified. In our work, the inter-turn short circuit stator fault is identified using the technique DWT.

Proposed Technology For Specified Problem

The rotating magnetic field of the motor induces the rotor voltage & currents at slip frequency and this produces an effective 3 phase magnetic field rotating at slip frequency with respect to rotor. The forward rotating field is created in symmetric cage winding & the backward rotating field at slip frequency with respect to rotor is created in asymmetric cage winding[11]. It creates an induced voltage at the corresponding frequency. The current frequency (f_{st}) appearing corresponds to the inter-turn short circuit faults is expressed as

$$f_{st} = f_s\left(\frac{m}{p}(1-s) \pm k\right) \quad (1)$$

Wavelet analysis is breaking up of a signal into shifted and scaled versions of the source wavelet. Wavelets are localized in both time and frequency domain and therefore suitable for signals whose spectral constant changes over time. Wavelet transform represents a signal with detail and approximation coefficients. These components cover the entire frequency spectrum with different band widths and whose frequency band depends on the sampling frequency (f_s). The highest band covers the frequency range $f_s/2$ to $f_s/4$; whereas the lowest band depends upon the decomposition levels. For next decomposition levels, the centre frequency and band width will be halved.

The selection of mother wavelet is arbitrary. In our work, the mother wavelet used is symmlet 8 with 8 decomposition levels for inter-turn short circuit fault identification.

DWT Based Fault Diagnosis – Result & Discussion

The test induction motor has the following specifications: 3 phase, 3hp, 415V, 1500rpm, 50Hz, with stator winding tapings. The stator current of this test motor is acquired under healthy and faulty condition with the sampling frequency of 20000Hz and with 2000 data samples. The inter-turn fault is created externally by short circuiting the terminals of the tapings. For testing purpose 8 turns of the stator winding are shorted externally. The healthy and faulty stator currents are analysed using DWT.

The healthy and faulty current spectrums under loaded condition of the induction motor are shown in fig1.

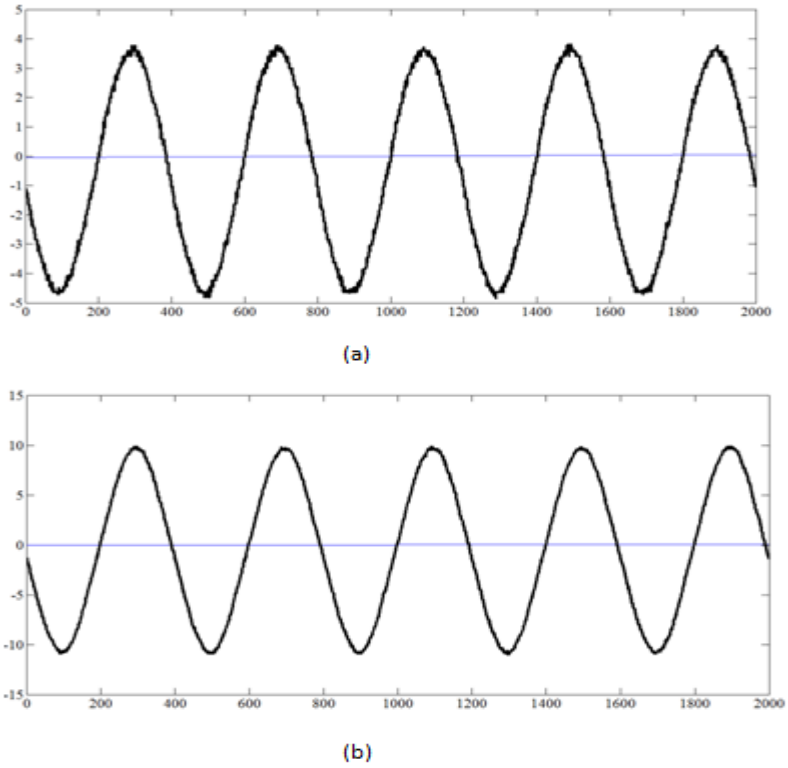


Figure1: Induction motor current (with same loading) under (a) healthy (b) faulty conditions

From fig1, for the same loading condition, the difference between the healthy and faulty conditions of the induction motors is shown only in amplitude. There is no other information about healthy and faulty induction motors. But every change in the induction motor is directly reflected on the induction motor stator current and therefore it is necessary to extract the features of the signals using some signal processing techniques. The technique used here for extracting the features of the signals is DWT, mother wavelet, symmlet with 8 decomposition levels. The fault indicators used in analysing the signal are wavelet coefficients and the statistical parameters of the wavelet coefficients.

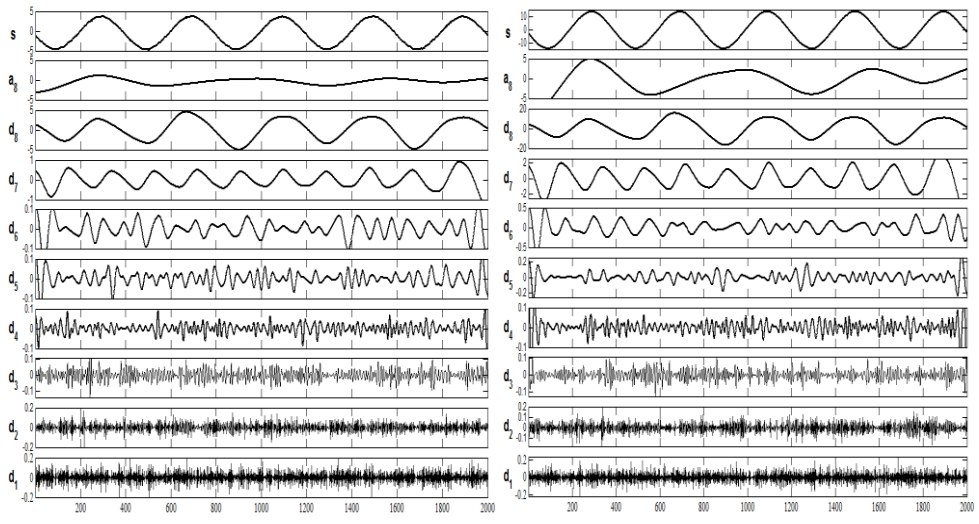
A. *Wavelet coefficients as fault indicators*

The sampling frequency of the data samples decides frequency band of the wavelet coefficients. The Multi-Resolution Analysis (MRA) decomposition levels and corresponding frequency ranges are given in tableI.

Table 1: MRA Decompostion Levels and corresponding Frequency Ranges

Decomposition levels	**Frequency ranges**
1	10000 to 5000
2	5000 to 2500
3	2500 to 1250
4	1250 to 625
5	625 to 312.5
6	312.5 to 156.25
7	156.25 to 78.125
8	78.125 to 39.0625

Using equation (1), the fault harmonic frequencies corresponding to the inter-turn fault created are frequencies are 75, 100, 125, 150, 175, 200, 225Hz..... They are covered in the frequency ranges with decomposition levels 6,7 &8. From the wavelet coefficients of the higher decomposition levels, the fault can be identified. The wavelet coefficients of different decomposition levels are shown in fig 2.



(a) (b)

Figure 2: Wavelet coefficients of induction motors under (a) healthy (b) faulty conditions

From the wavelet coefficients of the healthy and faulty conditions of the induction motors, it is clear that the higher decomposition levels corresponds to the fault frequencies and they are one of the fault indictors of inter-turn short circuit fault.

B. *Statistical parameter*

The statistical parameters are also one of the fault indicators of fault diagnosis. Table II shows some of the statistical parameters and its values under healthy and faulty conditions with original and synthesised signals.

Table 2: Statistical Parameters of Original & Synthesized Signal

Statistical parameters	**Original signal**		**Synthesised signal**	
	Healthy	**Faulty**	**Healthy**	**Faulty**
Mean	-0.5061	-0.4936	-0.5294	-0.5839
Median	-0.499	-0.424	-0.4178	-0.6947
Mode	-4.706	13.33	0.156	1.726
Max	3.8	13.7	1.081	4.914
Min	-4.85	-14.8	-3.187	-9.799
Range	8.65	28.5	4.268	14.71
Standard dev.	2.898	9.744	0.8461	2.905
Median abs. Dev.	2.889	9.676	0.5652	1.953
Mean abs. Dev.	2.605	8.719	0.6704	2.3
L1 norm	5251	17450	1481	4575
L2 norm	131.5	4362	44.63	132.5
Max. Norm	4.85	14.8	3.187	9.799

The statistical parameters of the faulty induction motors are high compared to the healthy ones. The statistical parameters of original signal are able to classify the healthy and faulty induction motors, but it fails to classify with some of the statistical parameters. Compared to the parameters of the original signal, the synthesized signal gives accurate solution or better classification between healthy and faulty induction motors with almost with all the statistical parameters.

Conclusion

In our paper the inter-turns short circuit fault is analysed using Discrete Wavelet Transform. The wavelet coefficients and statistical parameters are the fault indicators used in fault diagnosis. Wavelet analysis helps to distinguish the healthy and faulty induction motors.

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